National Aeronautics and Space Administration

NASA Case Study

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GOES-N: Long and Winding Road to Launch

Overview

Operating as a Two-Satellite Constellation 22,000 miles above Earth's Equator, the *GOES*[1] (Geostationary Operational Environmental Satellite) *Observatories* provided continuous meteorological coverage of 60% of the planet. *GOES-N*, the first in the next generation of *GOES* Spacecraft, would be the most advanced meteorological observation Satellite in space. See **Figure 1** for an artist's image of *GOES*.

Getting *GOES-N* into orbit, however, would prove to be difficult. The road to launch was marred by a series of unfortunate events, including lightning strikes in the vicinity of the rocket, launch-vehicle battery qualification issues, and Contractor technician strikes.

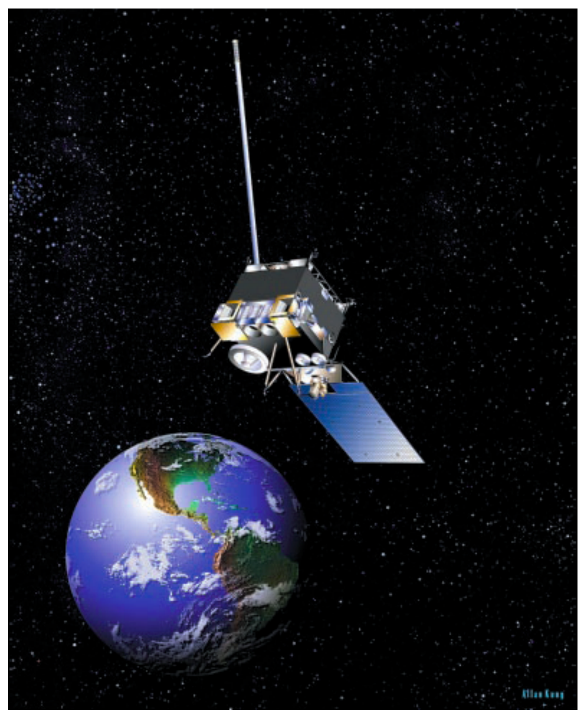

Figure 1: Artist's Depiction of GOES Overlooking Earth. Source: NASA Image.

[1] See **Appendix 1** for a list of case acronyms.

For months, *GOES-N* sat on the ground, stacked and waiting, riding out a sequence of delays and resets as Engineers and Managers wrestled with a string of issues.

By the summer of 2005, Ken Yienger, Systems Manager for *GOES-N*, wondered what's next? Ken said:

> *"You are always focused on making sure you have done everything possible to ensure a successful Mission right up to the moment of launch—testing, retesting, verifying, and validating everything multiple times. Then you close the launch vehicle fairing and say, 'Let's go!' You expect some unexpected things—bad weather that will delay you a day or so on the pad, or a Shuttle Mission might make you wait a few days. But nobody plans upfront to sit on the launch pad for a month."*

The *GOES-N* Team faced a host of technical and programmatic issues with Project members rescheduling their commitments and the original launch date of December 2004 receding in the rearview mirror. The 2005 hurricane season was fast approaching too. The critical question became: When has an *Observatory* and launch vehicle (LV) sat too long on the pad?

Best in the Sky

Developed by NASA for the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), *GOES* was essential for forecasting and tracking severe weather, such as hurricanes and tornadoes. *GOES* was known as the world's "eyes in the sky"—it was the only weather-forecasting tool for many of the 140 nations that received the Satellites' data. The global meteorological community relied on the *GOES* Satellites, which remained in one position relative to the rotating Earth, to send a continuous stream of weather and environmental data. The *Observatories* were also the linchpin to the Search and Rescue Satellite-Aided Tracking System (SARSAT) for tracking that relayed emergency signals sent from aircraft, marine SARSAT vessels, and emergency locator transmitters. Over the past 25 years, SARSAT, assisted by *GOES*, had initiated the rescue of more than 18,000 people.

GOES-N: Leading the Next Generation

A 3-axis stabilized Spacecraft built based on the *Boeing 601* heritage design, the *GOES-N* series of Satellites (including *GOES-O* and *GOES-P*) was designed for a nominal 10-year Mission life per Satellite with 14 years of fuel for each Satellite. The "stellar inertial-based" attitude-control system comprised 3 star trackers and a hemispherical inertial reference unit, or gyroscopes, for determination/control of direction; 4 reaction wheels to control the Spacecraft in the normal mode; and 12 two-pound thrusters to manage momentum and maintain orbital location.

GOES-N[2] carried a collection of Earth- and space-monitoring instruments that improved upon the previous technologies. It was built with more accurate prediction and tracking capabilities than any of its 12 predecessors. It was designed to improve, by a factor of 4, image accuracy in locating severe weather events, largely by virtue of its star-tracker navigation system. See **Figure 2** for a map of *GOES* coverage.

[2] GOES-N would be designated *GOES-13* once in geosynchronous orbit.

The primary instrument suite of *GOES-N* consisted of:

- Five-Channel Imager: a radiometer for producing images of the Earth's surface, oceans, storm development, cloud cover, cloud temperature and height, surface temperature, and water vapor. It was developed by ITT Corporation.
- Nineteen-Channel Sounder: a supplementary device to the imager for gathering data for determining atmospheric temperature and moisture profiles, surface and cloud-top temperatures, and ozone distributions. This was also built by ITT.
- Solar X-Ray Imager: providing for early detection and location of solar flares and for gauging flare intensity and duration. This instrument was developed by Lockheed Martin.
- Space Environment Monitor Instruments: including a three-axis magnetometer for measuring energy particles and the Earth's geomagnetic field. It was built by Science Applications International Corporation (SAIC), and a particle- and solar-monitoring suite from ATC (Assurance Technology Corporation)/Panametrics.

GOES-N boasted other enhancements: a digital transmission system for dissemination of data products that were distributed in analog format in the previous generation of *GOES* Satellites; an enhanced power subsystem using a single-panel solar array; and a Satellite lifetime design enhancement, boosting expected lifetime from 7 to 10 years and the expected propellant lifetime to 13.5 years.

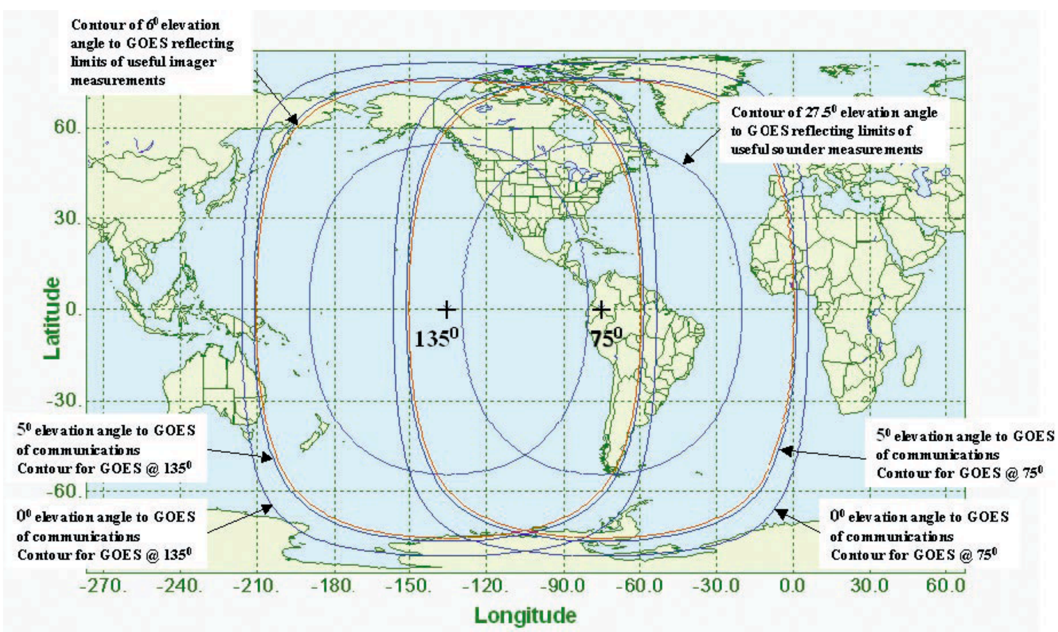

Figure 2: GOES Coverage Showing Continuous Observation of 60% of Earth, including the Entire Continental United States. *Source: NASA Image.*

The Project Team

Three organizations made up the main *GOES-N* Project Team. Boeing Satellite Systems, Inc., (BSS) was building the Satellite and Boeing Expendable Launch Services (BELS) was providing the launch vehicle, a *Delta IV* (4 + 2) rocket, as well as providing launch services. The Goddard Space Flight Center (GSFC) was procuring the *Observatory* components, including the *Observatory* and instruments, and was responsible for overseeing the development, testing, and operation of the Spacecraft, instruments, and ground equipment during the post-launch check-out phase, whereby the proper functioning of the Satellites was verified. The National Oceanic and Atmospheric Administration (NOAA) was responsible for the overall Program, funding, system on-orbit operation, and processing and dissemination of environmental Satellite data for the United States. It also had operational responsibility for the ground system.

BELS was to provide the launch services through a fixed-price "delivery-on-orbit" contract between NASA and BSS. The costs of any delays during the launch campaign—both *Observatory* and LV costs—would be borne by the Contractor. Under terms of the contract, there would be cost penalties for schedule-related delays that were exercised specifically by NASA—in other words, "NASA delays, NASA pays."

NASA and NOAA went into the *GOES-N* series acquisition with the mindset of a modified-commercial "delivery-on-orbit" approach. This used a firm fixed-price contract for both the *Observatory* development and launch services. While highly leveraging Boeing's experience in commercial Satellite development and operations, NASA focused its expertise and involvement on delivering the government-furnished equipment (GFE) instruments and on lowering and mitigating Mission risks. It did this by working whenever possible within the scope and terms of the existing contract.

As a result, although technically frustrating to the NASA Team, which wanted its own processes and styles to be followed, the arrangement meant, programmatically, that the risks and costs for schedule delays were borne by the prime Contractors rather than NASA/NOAA. Nonetheless, any unilateral direction given or implied by NASA would place larger financial burdens on the agencies for the costs of both the *Observatory* and LV Contractors.

Boeing was allowing 24 days after launching *GOES-N* for the Spacecraft to reach geosynchronous orbit at 22,240 miles, at which time the Satellite's instruments would be deployed and powered up. *GOES-N* would then be renamed *GOES-13* and turned over to NASA for the post-launch engineering checkout.

Eventually, *GOES-13* would be handed off to NOAA and placed in on-orbit storage mode. It would wait to be activated when either *GOES-11* (in the West) or *GOES-12* (in the East) suffered an anomaly or exhausted their fuel. Once called into service, *GOES-13* would deploy its instruments and begin its vigil of observing and measuring meteorological and environmental phenomena on Earth and in space.

Roadblocks…

But, getting *GOES-N* to launch was taking years. Issues relating to *Observatory* development accounted for very little of the time delay. Rather, several delays and resets had occurred due to LV-Related technical issues after the Spacecraft had completed *Observatory* environmental testing.

About midway through the development of the Spacecraft, the decision was made to manifest *GOES-N* through *GOES-P* on the new Boeing *Delta IV* launch vehicle. See **Figure 3** for an image of the *Delta IV* rocket. While the decision had little effect on the Spacecraft's design and testing, *GOES-N* was one of the first launches for the Boeing *Delta IVs*. As with all new LVs, development issues were causing the LV queue to slow down, while the early flight issues were addressed. In addition, because *GOES-N* was the first launch of this series of Spacecraft, NASA was more cautious with the launch windows, not allowing the launch of the *Observatory* during the Spring and autumnal eclipse periods. Those forces contributed to a slower-than-normal road to space.

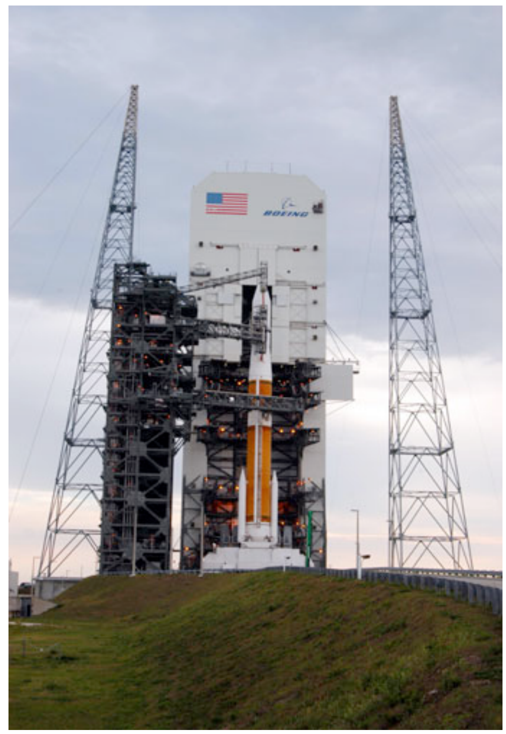

Figure 3: The Delta IV Rocket for GOES-N, Launch Complex 37 at Cape Canaveral Air Force Station. Source: NASA Image.

Still, by March 11, 2005, the Spacecraft had arrived at the launch site. Various tests had been completed, including Spacecraft functional testing, instrument testing and cleaning, and blanket closeout. An issue in a solar sensor was addressed too. Support Teams completed the *Observatory* battery-performance testing, or capacity check. On April 7, the Spacecraft was fueled. On May 25, 2005, the Spacecraft was mated to the payload attach fitting (PAF). It was encapsulated on June 3, and five days later it was transported to Cape Canaveral, Florida, in preparation for the initial June 23, 2005, launch date.

Then a combination of problems converged to delay the launch attempt until August 15. Technical issues emerged with the Spacecraft's communication boxes. A "close-in" lightning strike from a Summer thunderstorm required evaluation and testing. Further, there were ongoing issues with the launch vehicle's composite overwrapped pressure vessel (COPV) tanks[3]. For a Spacecraft Team, few things are more agonizing than having to wait while its Spacecraft sits on the launch pad.

[3] COPV tanks are containers for storing inert gases, such as helium and nitrogen.

Ken Yienger, the Systems Engineer, recalled the frustration:

> *"We had done everything we felt was necessary to launch, and had made some compromises to get where we were. We sat there, buttoned down in the fairing waiting for the next attempt, unable to fully and ideally test the Observatory as we'd like.*
>
> *Meanwhile, additional 'what ifs' and collateral hardware issues back at the factory continued to come across the radar screen. We alternated between being blessed with the GOES-O and GOES-P Observatories still being tested in the high bay—we could troubleshoot [resulting]anomalies on sister Spacecraft—to being cursed, since now all issues were 'launch liens', and needing to figure out, 'How are we going to test THAT in a launch vehicle fairing?'*
>
> *Each issue, individually, was one we felt we could chase to the ground, but like snowflakes each one can aggregate into a much bigger issue. At the end of the day, we had to keep asking: 'Are we still ready to launch?'"*

Prelaunch Reflections

It is August 14, 2005. As the *GOES-N* Mission Systems Engineer, Ken had retired all prelaunch actions successfully. Earlier in the day, the Launch Readiness Review (LRR) went well, and he received concurrence from NASA Headquarters (HQ) and GSFC management to proceed with the launch. Some of the key *Observatory* milestones over the past year were:

- The environmental (SCTV) testing, battery activation, and acceptance testing were completed in August 2004.
- Ambient performance testing, a comprehensive check, was done in December 2004.
- Battery performance was verified via a limited capacity check on March 25.
- The Spacecraft had been fueled and flight pressurized on April 7.
- The Spacecraft was encapsulated on June 8.
- Batteries had been charged to flight state of charge (SOC) (70% SOC) on July 18.[4]

Ken thought back on some of the distinguishing characteristics of the Mission.

GOES was a NASA "Class-B" Mission, meaning high-value/high-visibility. The replacement cost for the *GOES-N Observatory* was estimated at $500 million to $750 million. Launch delays were costly too. Commercial launch service meant "you stop, you pay." NASA-directed stand-downs incurred a penalty of $250,000 a day.

The launch service had a "ship and shoot" nature. This meant that testing capabilities at the launch site were limited by the availability of the mechanical/electrical ground support systems (MGSE/EGSE).

[4] See **Appendix 2** for the case timeline.

Also, there were typical testing restrictions on the pad due to the location and payload fairing (for example: testing was limited to the umbilical-provided services only, hard-line communications). Removing the Spacecraft from the LV (destacking) required a minimum of 25 days of work in order to get 5 days of vehicle-free testing. Technical hurdles exposed some personnel and management issues, such as the extent to which technical personnel played a role in assessing the launch risk, and in the go/no-go decision itself.

Foremost in Ken's mind were two questions: *What constitutes a reasonable on-ground duration without retesting? And how long is too long to sit?*

Decision Time

On August 18, *GOES-N* was still on the ground. Two launch attempts—August 15 and August 16—were unsuccessful. The first was unsuccessful due to a pressure drop in the LV related to the COPVs. The second launch was unsuccessful, because of a battery problem in the LV. The second attempt was suspended only 4 minutes and 20 seconds from launch. See **Figure 4** for an image of the rocket still waiting to launch.

To further complicate things, the LV's flight termination system (FTS) batteries expired. New ones would not be available for a minimum of three weeks—pushing the launch into the Autumn eclipse season. Based on all this information, the new launch date appeared to be November 2nd, outside the autumnal eclipse season.

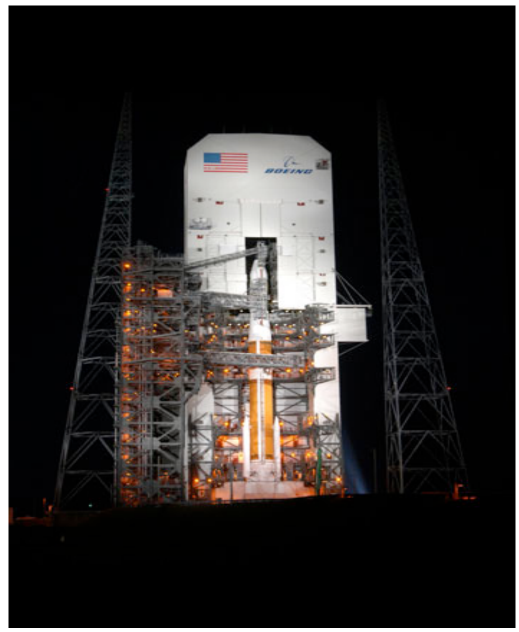

Figure 4: Still Standing Ready to Launch at Cape Canaveral. Source: NASA Image.

The *Observatory* had now been on the pad for two months, encapsulated for more than five months. Some of the tests had been done as long as a year ago. That nagging concern about on-ground duration kept coming back.

- What should Ken recommend to the Project Manager? Should they sit and wait, or restack, or perhaps retest? Should the Contractor make the call?
- What types of analyses should Ken recommend?
- What additional on-pad testing should be done?
- What criteria should Ken factor into his decisions?

Appendix 1

Case Acronyms

ATC	Assurance Technology Corporation
BELS	Boeing Expendable Launch Services
BSS	Boeing Satellite Systems, Inc.
COPV	composite overwrapped pressure vessel
FRR	Flight Readiness Review
FTS	flight termination system
GFE	government-furnished equipment
GOES	*Geostationary Operational Environmental Satellite*
GSFC	Goddard Space Flight Center
HQ	Headquarters
LRR	Launch Readiness Review
LV	launch vehicle
MGSE/EGSE	mechanical/electrical ground support systems
MRB	Mission Readiness Briefing
MRR	Mission Readiness Review
NASA	National Aeronautic and Space Administration
NOAA	National Oceanic and Atmospheric Administration
PAF	payload attach fitting
SAIC	Science Applications International Corporation
SARSAT	Search and Rescue Satellite-Aided Tracking System
SCTV	environmental testing
SMARR	Safety and Mission Assurance Readiness Review
SOC	state of charge

Appendix 2

GOES-N Launch Case Timeline

Date	Event
January 1998	Contract signed to procure next-generation weather Satellites.
2001	Originally scheduled for launch in 2001; construction/launch extended to 2003, because the *GOES* Satellites already on orbit are working well.
2003	Scheduled for launch in December 2004, then January 2005.
Early 2005	Launch date reset to May 2005 to avoid launching during Spring eclipse season.
April 2005	Concern about *Delta IV* rocket delays postpones to June; tanks replaced.
May 27, 2005	Mission Readiness Review (MRR).
June 2005	June 7: Safety and Mission Assurance Readiness Review (SMARR). June 13: NASA HQ Mission Readiness Briefing (MRB). Mid June: Launch slips to late June to allow time to check for possible damage to rocket's electrical systems from lightning strikes. Late June: Uncertainty about a rocket battery postpones launch to July.
July 2005	Technical concerns about launch vehicle and Satellite delayed to August. July 22: Flight Readiness Review (FRR).
Aug. 14, 2005	Launch Readiness Review (LRR).
Aug. 16, 2005	Launch aborted with 4 minutes and 22 seconds to go.

Source: NASA, "*GOES-N* Launch Saga Timeline," Available at http://goes.gsfc.nasa.gov/text/goesnstatus.html, Accessed on May 18, 2014.